Intelligent Vehicles and Road Surface Interaction: Roads That Can Be Read

Cherif Amer-Yahia, PhD, PE
Todd Majidzadeh
Visible Road Markings:

• Crucial for the interaction between road infrastructure and future intelligent vehicles

• Their absence negates the safety benefits that arise from Lane Departure Warning (LDW) in new vehicles

• Their under-maintenance represents a hazard for road users

• A high percentage of US highway fatalities are related to deficient roadway conditions and road markings
Intelligent Vehicles

Intelligent Vehicles Equipped With:

• Lane Departure Warning (LDW)
• Lane Keeping Assistant (LKA)
• Traffic Sign Recognition (TSR)

- Require pavement markings and traffic signs to be sustained at a minimum standard
- Alert drivers when they are passing over edge lines, keep them from drifting or colliding.
Effective road markings must be clearly visible to the driver day and night, in all weather conditions

- Luminance: how well the marking stands out on the road
- Retro-reflectivity: the amount of light reflected back to the driver to make the markings visible
Retro-reflectivity of road markings has a significant effect on safety.

Presence of road markings must be recognized, retro-reflectivity performance should be recorded.

So...

• How much retro-reflectivity do drivers need?
• How should it be measured?
• Should there be minimum requirements?
Pavement marking characteristics and warranting criteria are described in the Manual on Uniform Traffic Control Devices (MUTCD).

MUTCD requires transportation agencies to maintain longitudinal pavement markings to a minimum level of retro-reflectivity.
Retro-Reflectivity Measurement: Automated Methods

- Pavement marking retro-reflectivity is measured and directly compared to the minimum levels using handheld devices or mobile devices.
- Measurements are done using standard 30-meter geometry.
**MINIMUM MAINTAINED RETRO-REFLECTIVITY LEVELS**

FOR LONGITUDINAL PAVEMENT MARKINGS

1.) Measured at standard 30-meters geometry in units of mcd/m²/lux  (1 lux = 93 mcd at one foot).

2.) Exceptions - minimum pavement marking retro-reflectivity levels are not applicable:
   - As long as the Reflective Raised Pavement Markers (RRPMs) are maintained so that at least 3 RRPMs are visible from any position along that line during nighttime conditions
   - When continuous roadway lighting assures that the markings are visible

<table>
<thead>
<tr>
<th>Road type</th>
<th>Posted Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35-50</td>
</tr>
<tr>
<td>≤ 30</td>
<td>≥ 55</td>
</tr>
<tr>
<td>Two-lane roads² with center line markings only</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>250</td>
</tr>
<tr>
<td>All other roads²</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
MOBILE RETRO-REFLECTOMETER

- Records 400 measurements per second, ensuring continuous coverage of line markings
- Software works on any device with a Wifi connection and web browser
HANDHELD RETRO-REFLECTOMETER

• Measures retro-reflectivity of white and yellow pavement markings
• Software exports the data in CSV, KML, XML, and Shape-file formats for maximum compatibility with most GIS databases
RESOURCE INTERNATIONAL, INC.'S CONTRIBUTION

- Our technologists are striving to be a part of the integration of road maintenance concepts into the development of roads that can be “read” by intelligent vehicles.
- We propose the idea of using InfraRed (IR) Thermography as a tool to perform retro-reflective measurements of pavement markings at traffic speed.
Our vision is limited to a very small portion of electromagnetic spectrum.

Thermal energy has a much longer wavelength than visible light. Human eye can’t see it, just like it can’t see radio wave.

With thermal imaging, the portion of the spectrum we perceive is expanded helping us to see and measure thermal energy emitted from an object.

In the infrared world, everything above absolute zero emits heat so you can see equally well in highly lit and totally dark environments.
INFRARED THERMOGRAPHY

- Converts infrared energy (radiant heat) into an image that a person can see and understand.
- Infrared energy emitted from an object is directly proportional to its temperature.
- Radiant heat can be precisely measured to identify and evaluate the relative severity of heat-related problems.
Firefighting Applications

- IR help firefighters to find trapped victims through dense smoke or darkness.
- Thermal imaging can rapidly and accurately identify hot spots and the progress of the fire.
- Cold spots can easily be identified prior to firefighters being committed into the structure.
HIGHWAY STRUCTURE APPLICATIONS

- IR system are often used to identify and locate delamination in concrete bridge decks.
- System is mounted on moving vehicle to scan bridge decks at highway speed.
- Piers and other bridge concrete structures can be scanned from the ground or a boat.
BRIDGE DECK DELAMINATION MAP
**Application of Thermography to Lane Markings**

- Thermography directly senses emitted infrared radiation, and what is detected is the strength and location of thermal anomalies.

- By directly measuring radiant emission, thermography detects differences in surface temperature at the top of the pavement.

- The concept behind the application of IR technology is that surface features, such as a coat of paint, which is generally a thermal insulator, limits the heat transfer from the pavement to air, and appear with different radiant temperatures (cold spots) on IR images.
APPLICATION OF THERMOGRAPHY TO LANE MARKING

Camera Image

Thermal Image
APPLICATION OF THERMOGRAPHY TO LANE MARKING

Visual Image

Thermal Image
INDICATORS OF MAINTAINED LONGITUDINAL PAVEMENT MARKINGS

Two possible indicators of maintained longitudinal pavement markings

- Visual Image
- Temperature
Creating a Relationship Between Retro-Reflectivity and Radiant Heat

- Determine minimum pavement marking retro-reflectivity level on a section of the project using a hand-held or mobile retro-reflectometer
- On the same project section, determine the maximum temperature corresponding to the minimum pavement marking retro-reflectivity level using the IR survey system
- Create a relationship between retro-reflectivity and radiant heat (temperature)
- Derive maximum maintained temperature levels for longitudinal pavement markings for the project
Conclusions

• Hundreds of miles of collected data in a single day
• Surveys are carried out at highway speed with no traffic disruption or safety risk
• A single IR vehicle pass covers an entire lane including both the left and right lane markings
• Cost effective survey method
• Locations of lane markings needing maintenance are reported with GPS coordinates
Thank You!

Cherif Amer-Yahia, PhD, PE  
Director, NDT & Technology Division  
cherifa@resourceinternational.com  
www.resourceinternational.com

Todd Majidzadeh  
Executive Vice President, Technology  
toddm@resourceinternational.com  
www.resourceinternational.com